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FORUM
toxic knowledge: a mercurial fugue in three parts

IN A PROVOCATIVE DISCUSSION on the nature and historicity of scientific knowledge, Bruno Latour asks: "Where were microbes before Pasteur?" He concludes: "*after* 1864 airborne germs were there all along," which presents the historian with an interesting portal into the history of scientific knowledge and its relationship with environmental politics. The history of toxic environments is largely reactionary in nature: the framing of new environmental standards comes in response to the discovery of hazards and those standards are frequently revised as new information becomes available. Reactionary history and the changing contexts of awareness of toxic hazards are suggestive of what Latour called the "historicity" of scientific knowledge: "History not only passes but transforms."[1] Scientific discoveries alter our reading of the past. Drawing on a similar epistemological trope, this essay surveys the histories of knowing and unknowing surrounding a series of confusions related to the discovery of mercury contamination in rivers and lakes in the northern hemisphere between the 1960s and 1980s. In so doing, it offers an index toward thinking historically about toxic bodies and toxic environments.

Chemistry is the science of material change and the scientific knowledge developed to understand these changes offers an opportunity for environmental historians to tell stories about stories about nature. Chemical knowledge has been pivotal in human interactions with nature, and the accounts that follow rely

Michael Egan, "Toxic Knowledge: A Mercurial Fugue in Three Parts," *Environmental History* 13 (October 2008): 636-642.

heavily on the polity of a constructed scientific knowledge. In addition to the prospect of chemistry offering insight into constructions of science as they relate to environmental history, however, one might also recognize the material significance of chemicals to environmental narratives. Studying landscapes in which various natural and synthetic chemicals come together to form insalubrious settings for organic beings also presents new opportunities for considering nonhuman agency in our environmental histories. In all three snapshots of toxic environments that I present in discussing mercury pollution, mercury's chemical make-up undergoes changes that are only partly influenced by human activities. Weaving together narratives of chemical knowledge and toxic environments, then, offers ways of complicating our environmental histories.

The most common form of mercury poisoning involves methylmercury, an organic mercury compound that accumulates in humans and animals and acts as a highly dangerous neurotoxin. The issue that plagued the scientists from Sweden, Canada, and the United States, whose research comprises the main thrust of this work, was that methylmercury was appearing in freshwater systems where it did not belong. The absence of a scientific rationale for methylmercury's presence in the places it was being discovered mystified researchers until a number of breakthroughs in understanding resolved their confusion and painted a troubling canvas of the complexity and severity of the global mercury pollution problem.

In the early 1950s, Swedish conservationists observed a marked reduction in the populations of seed-eating birds while also encountering more bird carcasses around the countryside, which were found to contain staggering amounts of mercury. By 1960, predatory birds also were found to have elevated levels of mercury in their systems. The high mercury content ultimately was traced to the use of mercury in agricultural fungicides and the treatment of seedgrain.[2] During the investigations into the source of mercury in birds, scientists began considering the repercussions if mercury used in agriculture should find its way into freshwater systems. According to one account on the Swedish response to mercury pollution, "not much imagination was needed to realize the potential hazard to human health of the mercury in fish."[3] In 1964, teams of scientists began taking samples of fish from several bodies of freshwater in Sweden.[4] In short order, they found alarmingly high levels of methylmercury, the quantities of which indicated that they could not be attributed solely to the mercury treatment of seedgrain.[5]

In Sweden, scientists knew that mercury was emitted into rivers and lakes from three industrial sources. The paper mills used phenylmercury to prohibit the formation of mucus in the paper machines; the pulp industry also used phenylmercury to protect wet mechanical wood pulp from mould fungi; and the chloralkali industry emitted ionic mercury in its electrolysis wastewater. These inorganic forms of mercury were relatively nontoxic, unlike the methylmercury that had been discharged into the waters near Minamata in the early 1950s. And yet, methylmercury—responsible for the devastating cases of mercury poisoning in Japan—was prevalent throughout Swedish river systems. In 1966, acting on suspicion rather than evidence, several different Swedish researchers proposed that methylmercury was somehow created by bacterial action. Microbial activity in the mud on lake bottoms, they posited, could methylate inorganic and metallic mercury. The following year, Sören Jensen and Arne Jernelöv confirmed this hypothesis, showing that bacteria methylated mercury in anaerobic (oxygen-free) ecosystems, but they could not explain how.[6] By 1968, another team of scientists found that microorganisms in the sediment of river and lake bottoms metabolized inorganic and metallic mercury, and excreted them as methylmercury.[7] While the scientific work constituted an important breakthrough in understanding mercury's characteristics in the environment, the repercussions of the discovery were devastating. No matter what its form—or however benign—when entering the ecosystem, mercury now constituted a serious threat to human health. If biological systems could convert less harmful mercury compounds into a harmful, lipid-soluble form—methylmercury—then mercury use in industry posed grave and long-term health problems.

IN JUNE 1968, A CONFERENCE on the toxicity of persistent pesticides was convened at the University of Rochester. Among those invited were several of the scientists whose research had illuminated the severity of the mercury problem in Sweden. As they presented their results on mercury contamination in Swedish waters, American participants tried to identify the sources of Swedish exceptionalism. Why had Sweden suffered from such a calamitous pollution problem when other countries—and especially the United States—had not? When one biologist, Thomas Clarkson of the University of Rochester, hypothesized that mercury compounds might have been used in Sweden longer than they had in other countries, Alf Johnels of the National Museum of Natural History in Stockholm corrected him, stating that Sweden had copied American industrial mercury practices. Mercury compounds in chloralkali production had been used for longer and in significantly greater proportions in the United States.[8] Indeed, where Sweden lost almost 20,000 kgs of mercury to the environment in 1967, American industry and agriculture lost an estimated 600,000-650,000 kgs.[9] So what was it, then? The northern climate, perhaps? The geography? Some speculated that Sweden's archipelagoes kept water from circulating. Indeed, some present made the connection between the Swedish incident and the massive mercury poisoning at Minamata in Japan, also a geography of protected sea waters. Gently, the Swedes and some of the more concerned American scientists suggested the real distinction between Sweden and the United States stemmed from the fact that Sweden actually was looking for mercury.[10]

Sure enough, in 1969, shortly after the Rochester conference, the Canadian Department of Fisheries and Forestry banned commercial fishing catches from a number of lakes and rivers in Manitoba. More than a million pounds of fish that contained mercury in quantities of 5 to 10 ppm—ten to twenty times the government-ordained action level—were confiscated and destroyed.[11] Then, in March 1970, Norvald Fimreite, a zoology student at the University of Western

Ontario, reported to the Canadian Department of Fisheries and Forestry that he had found 7.09 ppm mercury in pickerel from waters that fed Lake Erie. Fimreite's discovery prompted rapid action from the Canadian government, which identified chloralkali plants as the source and forced them to eliminate mercury from their operations. In addition, the government banned the taking of fish–sport or commercial–in the area, and threatened polluters with legal action. All this within a month of Fimreite's letter. In *The Closing Circle*, the biologist Barry Commoner remarked that Fimreite undoubtedly held "the world record ... for the fastest, one-man, large-scale ecological action."[12]

Ultimately, the reason mercury contamination had not become a serious ecological problem in the North American context had everything to do with the fact that nobody was looking for it, which raises some interesting questions surrounding the sociology of scientific knowledge and its role in defining toxic knowledge and ecological problems. ("Where were microbes before Pasteur?") What the Swedish and Canadian lessons taught was that when organic pollutants enriched river systems, the nutrients fed aquatic plants and microbes would thrive and methylate more mercury. One of the major environmental projects of the late 1960s and early 1970s was the reduction and–in many cases–elimination of mercury from industrial production. While Canada and the United States set mercury limits at 500 ppb in the aftermath of Swedish contamination and at the outbreak of their own nightmares, by 1976, the World Health Organization had determined that 200 ppb might serve as a better threshold for the concentration of methylmercury required to yield the classic symptoms of Minamata disease. That number was reduced by a factor of ten in 1990 to 20 ppb.[13]

IT WAS DURING AND AFTER THIS cleanup that another methylmercury mystery presented itself. In 1975, a team headed by University of New Mexico biologist Loren Potter sought to establish baseline levels of mercury in predatory fish in the Lake Powell reservoir in order to predict the effects of future industrial and recreational developments. Lake Powell was a Bureau of Reclamation storage and hydroelectric generation reservoir, initially impounded in 1963. It served as a good test site, the subsequent article argued, because it was "a new reservoir remote from major man-caused pollution sources."[14] Their findings revealed disproportionately high levels of mercury at the top of the artificial lake's food chain. Walleye taken from Lake Powell averaged 427 ppb mercury in their axial muscle, and bass averaged 314 ppb. In the aftermath of the Swedish alarm, both Canada and the United States had set acceptable limits of 500 ppb mercury in commercial and recreational fish consumption. The predatory fish in Lake Powell were just under that limit, but Potter and his colleagues were astonished to discover that the mercury levels were that high; given the absence of industrial pollutants, the mercury levels should have been substantially lower. "Due to bioamplification, mercury concentrations of nonacceptable amounts by FDA standards are being approached in the higher trophic levels," they warned. "If a mercury content above 500 ppb is confirmed as common to the muscle of large game fish, mercury levels could become a significant factor in the management of the Lake Powell fishery."[15]

The mercury content in Lake Powell was not an isolated incident. In 1977, environmental engineers identified high levels of methylmercury in largemouth bass in three new reservoirs on the Savannah River and its tributaries in western South Carolina.[16] Similar discoveries were made in Finland and in northern Quebec, Manitoba, and Labrador, all in sites with little or no industrial pollution.[17] Following on from the Swedish studies, Frank D'Itri, a water chemist at Michigan State University, had proposed that the high volatility of mercury explained the contamination of fish located far from industrial mercury emissions. Mercury's volatility–its tendency to pass into a gaseous state–suggested its ability to travel significant distances by air.[18] This is what made mercury such a serious environmental hazard; its capacity to travel in the air and pollute not just local waters, but distant waters as well. But while methylmercury was accumulating in disproportionate quantities in human-made hydroelectric reservoirs, adjacent, unimpounded lakes did not show concomitant signs of increased mercury burden. If distant sources of pollution–coal-fired power generators, pulp and paper mills, and chloralkali manufacturers–were the cause of methylmercury deposits as D'Itri had posited, then why were they concentrating in new reservoirs and not elsewhere to the same extent?

In the early 1980s, Canadian researchers demonstrated that methylmercury bioaccumulation in nonpolluted reservoirs was not the product of distant industrial activity, but resulted from microbial activity on flooded, decaying organic matter that contained inorganic mercury.[19] Rising water levels in new reservoirs enveloped naturally occurring mercury present in the terrestrial environment and also flooded vegetation and soils rich in organic carbon. Their decomposition created the conditions through which the microbial methylation of inorganic mercury was fueled.[20] Just as in the Swedish example, the discovery of inorganic mercury in the environment stressed its hazardous potential when methylated. But unlike the Swedish example, in the instance surrounding impounded lakes, natural mercury deposits interacted with artificially flooded reservoirs to introduce methylmercury; humans had not introduced mercury into the ecosystem. This discovery prompted the continuing study of mercury methylation in shallow marshes and natural wetlands where the flooding of vegetation occurs without human influence.

IN CONCLUSION, some comments or observations, which aim to situate the history of toxic environments more firmly within the purview of environmental historians and their historiographies. The short of it is this: beyond drawing on themes like health, pollution, and the hubris of new and ambitious technologies, histories of toxicological sciences and politics provide environmental historians with an interesting opportunity to engage with themes of natural agency in heretofore unexamined ways. A seductive, intellectual paradox exists in the nature of the methylation of mercury in hydroelectric reservoirs; the *containment* of water in the reservoirs resulted in the *release* of another natural phenomenon. Mercury's transition from elemental isolation to unwelcome ecological integration offers an intriguing blend of human and natural partnerships of the sort that make environmental history an important avenue for historical and environmental inquiry. On the one hand, my accounts of the release of methylmercury belong to a long and well-documented history of the tragedy of unintended toxic consequences spurred by technology and visions of progress. On the other, they offer an interesting opportunity to engage with themes of natural agency in heretofore underexamined ways. Mercury has a nature. Its transmutation into the toxic methylmercury when it "communicates" with microbes in polluted water systems and in hydroelectric reservoirs occurs at a curious intersection between human and nonhuman activity. The construction of hydroelectric reservoirs provides the context for this communication, but the creation of methylmercury is a distinctly nonhuman occurrence that alters human and ecological landscapes. In mercury's transformation into and release as a toxic vapor, nature suggests an agency that palpably shapes how mercury and humanity mix.

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NOTES

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2. For an overview, see Lennart J. Lundqvist, *The Case of Mercury Pollution in Sweden: Scientific Information and Public Response* (Stockholm: Swedish Natural Science Research Council, 1974), 12-25. See also Katherine and Peter Montague, *Mercury* (San Francisco: Sierra Club Books, 1971), 34-37; and Patricia A. D'Itri and Frank M. D'Itri, *Mercury Contamination: A Human Tragedy* (New York: John Wiley & Sons, 1977), 29-34.
3. Lundqvist, *The Case of Mercury Pollution in Sweden*, 29.
4. Ibid., 26.
5. T. Westermark, *Kvicksilverfrågan i Sverige* (Stockholm: Ministry of Agriculture, 1965), 25. See also Gunnel Westöö, "Methylmercury Compounds in Fish: Identification and Determination," *Acta Chemica Scandinavica* 20 (1966): 2131-37.
6. Sören Jensen and Arne Jernelöv, "Biosyntes av Metylkvicksilver I," *Biocidinformation* 10 (May 1967): 4-5. See also Jensen and Jernelöv, "Biosyntes av Metylkvicksilver II," *Biocidinformation* 14 (February 1968): 3-5. Jensen and Jernelöv published their findings in English in *Nature* in 1969. See Jensen and Jernelöv, "Biological Methylation of Mercury in Aquatic Organisms," *Nature* 223 (August 16, 1969): 753-54.
7. J. M. Wood et al., "Synthesis of Methyl-mercury Compounds by Extracts of a Methanogenic Bacterium," *Nature* 220 (October 12, 1968): 173-74.
8. Morton W. Miller and George G. Berg, eds., *Chemical Fallout: Current Research on Persistent Pesticides* (Springfield, IL: Charles C. Thomas Publishers, 1969), 91.
9. A. Hanson, "Man-made Source of Mercury," in *Mercury in Man's Environment* (Ottawa: Royal Society of Canada, 1971); and R. L. Mitchell, "Mercury Consumption Survey, April

10, 1969," The Chlorine Institute, 1969.

10. Miller and Berg, eds., *Chemical Fallout*, 90-93.
11. E. G. Bligh, "Mercury and the Contamination of Freshwater Fish" (Winnipeg: Fisheries Research Board of Canada, Manuscript Report # 1088, 1970); and G. Wobeser et al., "Mercury Concentration in Tissues of Fish from the Saskatchewan River," *Journal of the Fisheries Research Board of Canada* 27 (1970): 830-34.
12. Barry Commoner, *The Closing Circle* (New York: Alfred A. Knopf, 1971), 202.
13. World Health Organization, *Environmental Health Criteria 1: Mercury* (Geneva: World Health Organization, 1976).
14. Loren Potter et al., "Mercury Levels in Lake Powell: Bioamplification of Mercury in a Man-made Desert Reservoir," *Environmental Science and Technology* 9 (January 1975): 41-46, quotation on 41.
15. Potter et al., "Mercury Levels in Lake Powell," 44.
16. A. R. Abernathy and P. M. Cumbie, "Mercury Accumulation by Largemouth Bass (*Micropterus salmoides*) in Recently Impounded Reservoirs," *Bulletin of Environmental Contamination and Toxicology* 17 (1977): 595-602.
17. For Finland, see Martin Lodenius et al., "Accumulation of Mercury in Fish and Man from Reservoirs in Northern Finland," *Water, Air, and Soil Pollution* 19 (1983); 237-46; M. Verta et al., "Causes of Increased Mercury Levels in Finnish Reservoirs," Publications of the Water Research Institute, National Board of Waters, Finland 65 (1986), 44-58; and P. Porvari, "Development of Fish Mercury Concentrations in Finnish Reservoirs from 1979-1994," *Science of the Total Environment* 213 (1998): 279-90. For Canada, see R. A. Bodaly et al., "Increases in Fish Mercury Levels in Lakes Flooded by the Churchill River Diversion, Northern Manitoba," *The Canadian Journal of Fisheries and Aquatic Sciences* 41 (1984): 682-91; R. Boucher et al., "Teneur en mercure des poissons des réservoirs La Grande 2 et Opinaca (Québec, Canada) avant et après la mise en eau," *Revue Française des Sciences de l'Eau* 4 (1985): 193-206; and W. J. Bruce and K. D. Spencer, "Mercury Levels in Labrador Fish, 1977-78," *Canadian Industry Report of Fisheries and Aquatic Sciences* 111 (1979): 1-12.
18. Frank D'Itri, *The Environmental Mercury Problem* (Cleveland: The Chemical Rubber Company Press, 1972), 89-90.
19. Bodaly et al., "Increases in Fish Mercury." See also R. E. Hecky et al., "Increased Methylmercury Contamination in Fish in Newly Formed Freshwater Reservoirs," in *Advances in Mercury Toxicology*, ed. T. Suzuki et al. (New York: Plenum Press, 1991), 33-52.
20. B. D. Hall et al., "Impacts of Reservoir Creation on the Biogeochemical Cycling of Methyl Mercury and Total Mercury in Boreal Upland Forests," *Ecosystems* 8 (2005): 248-66.